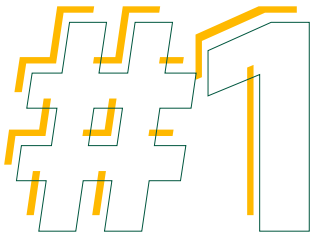
SUSTAINABILITY IN MATERIAL HANDLING

HOW AUTOMATED WAREHOUSE SYSTEMS COMBINE EFFICIENCY AND FUTURE VIABILITY

JUNGHEINRICH

INDEX

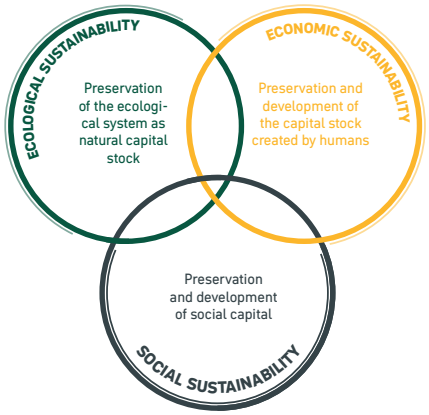


SUSTAINABILITY IN MATERIAL HANDLING

Companies today are faced with the challenge of reconciling profitability and sustainability – under increasingly complex conditions: High energy prices, growing demands from customers, investors or employees, as well as regulatory requirements, are increasing the pressure on companies. National and international initiatives such as the EU Taxonomy or the German Supply Chain Act provide clear requirements for sustainable and transparent business practices. At the same time, ESG criteria (Environmental, Social, Governance) are establishing themselves as central benchmarks for evaluating corporate sustainability performance.

However, all of this presents not only a challenge but also a significant opportunity. Studies show that companies prioritising sustainability are demonstrably more successful[1]. Sustainability has now become a strategic success factor, even in material handling.

But what exactly does sustainability mean? Sustainability is often interpreted according to the so-called three-pillar model, which considers ecological, economic, and social dimensions in equal measure. In practice, this means: climate protection, efficiency, and social responsibility are not mutually exclusive. On the contrary: they are interdependent and lead to more competitive and future-proof companies.



Particularly in material handling, developments such as digitalisation, artificial intelligence and automation are opening new possibilities for efficiently managing material flows, reducing energy consumption and emissions, optimising inventories and order processing, and making optimal use of space. At the same time, these technologies help to use resources wisely and ensure the safety of employees and sensitive goods. In this way, material handling not only enhances profitability but also drives sustainable transformation.

Against this backdrop, it is useful to analyse specific components of material handling, such as automated storage and material flow systems and the associated ASRS solutions (automated storage and retrieval systems), in terms of their sustainability potential. In the following chapters, we will explore the contributions these can make to resource conservation, energy efficiency and social sustainability. In addition, we present successful use cases and outline how companies can successfully integrate an automated warehouse system.

1) This is demonstrated, for instance, by a meta-study conducted by the University of Oxford. 88% of the examined sources conclude that these companies demonstrate better operational performance. Cf. From the stockholder to the stakeholder: How sustainability can drive financial outperformance. University of Oxford/Arabesque Partners, Social Science Research Network, 2015.

#2 OVERVIEW OF AUTOMATED WAREHOUSE SYSTEMS

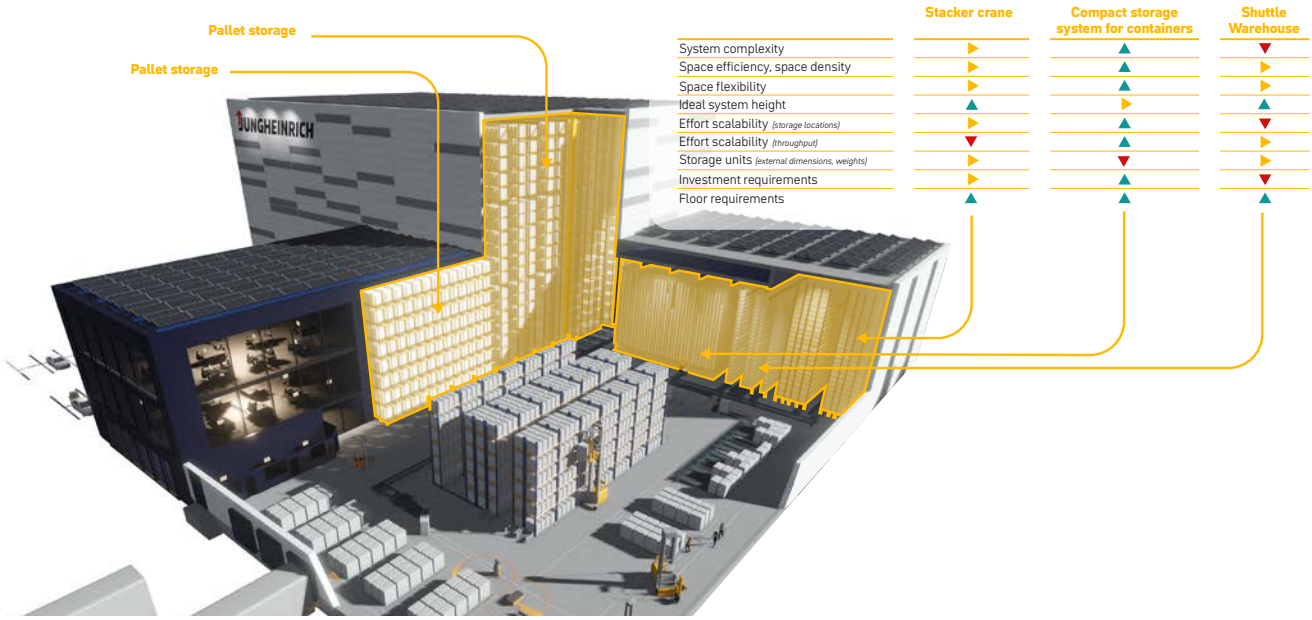
For the analysis of the sustainability potential of automated storage and material flow systems, it is initially useful to clearly distinguish the individual terms and components. In this white paper, we discuss ASRS solutions (automated storage and retrieval systems) as part of an overall system in the automated warehouse. We examine the sustainable effects of individual ASRS technologies, but with a particular focus on the sustainability of complete automated systems.

In this white paper, we differentiate ASRS into three technologies:

- Stacker cranes (pallet stacker crane, small parts stacker crane)
- Shuttle systems (container shuttle, pallet shuttle)
- Compact container storage systems

These three automated storage and retrieval systems are characterised by shared strengths: They ensure precise storage and retrieval, enable high throughput, and, thanks to their compactness, make optimum use of the available space.

Despite their similarities, the systems differ in key features. We have summarised these in an overview, using the example of small parts ASRS:



These ASRS solutions are integrated into an overall system in an automated warehouse, e.g. with mobile robots such as AGVs or AMRs, automated conveyor and picking technology and warehouse management software (WMS). It is precisely this interaction that results in a variety of positive sustainability effects – for instance, through energy savings, optimised, nearly error-free processes and ergonomic relief for employees.

The technologies described are becoming increasingly significant in practice: given the growing demands for efficiency and sustainability, an increasing number of companies in industry and trade are relying on **automated warehouse systems**. According to current market analyses, **an annual increase of 8%**[2] **is expected until 2030**. Thus, ASRS solutions will become key tools for combining ecological and economic objectives in material handling in the future.

2) Source: https://www.grandviewresearch.com/industry-analysis/automated-storage-retrieval-system-market-report, as of 21/05/2025

#3 SUSTAINABILITY ASPECTS OF AUTOMATED WAREHOUSE SYSTEMS

3.1 OPTIMISED USE OF AREA AND SPACE

Sustainability in material handling does not begin with the use of efficient technologies – the planning and construction of a warehouse are also critical factors. This is where automated warehouse systems with ASRS solutions reveal their full potential: due to their more compact vertical structure (high-bay warehouses), they enable significantly more efficient use of space and area – with measurable benefits for economic efficiency and the environment.

A central factor lies in the building itself. This is because the majority of emissions occur during construction. After 10 years, the construction of the building still accounts for 90% of the total emissions, and only after 30 years does this share drop to around 40%[3]. A large part of the ecological impact of a warehouse is therefore determined during its construction – and it is precisely here that automated warehouse systems provide a significant advantage through their structural efficiency.

A particularly resource-efficient concept is the silo construction method. In this case, the racking system itself assumes the load-bearing function for the roof and walls. Rather than building a structure around the warehouse – the warehouse is an integral part of the building design. This reduces material usage, shortens construction time and allows for a highly efficient use of space; for instance, automated small parts warehouses can be well over 20 m high, and automated pallet warehouses can exceed 40 m.

The vertical construction approach has a decisive effect: the required floor area can be significantly reduced, or more warehouse capacity can be created on the same area, thereby reducing both the ecological footprint and soil surface sealing.[4] **According to a study by 4flow[5], automated warehouses can save up to 20% on space.**

3) Cf. Sustainable Logistics and Supply Chain Management: Principles and Practices for Sustainable Operations and Management. David B. Grant, Alexander Trautrims, Chee Yew Wong. Kogan Page, 2022.

4) Soil surface sealing is a crucial aspect of environmental protection: "According to the official statistics of federal land usage, on average over the four years 2019 to 2022, approximately 52 hectares were newly designated as settlement and traffic areas daily. This equates to an area roughly the size of 72 football fields each day." By 2030, the aim is to reduce this area to under 30 hectares per day and achieve net-zero land consumption by 2050, in line with a circular land use economy. Source: https://www.bmuv.de/themen/nachhaltigkeit/strategie-und-umsetzung/reduzierung-des-flaechenverbrauchs?utm_source=chatgpt.com, as at 21/05/2025.

5) 4flow study: Sustainable warehousing: Practical measures for emission and cost reduction. Tom Binsfeld, Jan-Niklas Grafe, Wendelin Gross, Iwan Nikitin, Jan Oppermann, p. 12.

#3 SUSTAINABILITY ASPECTS OF AUTOMATED WAREHOUSE SYSTEMS

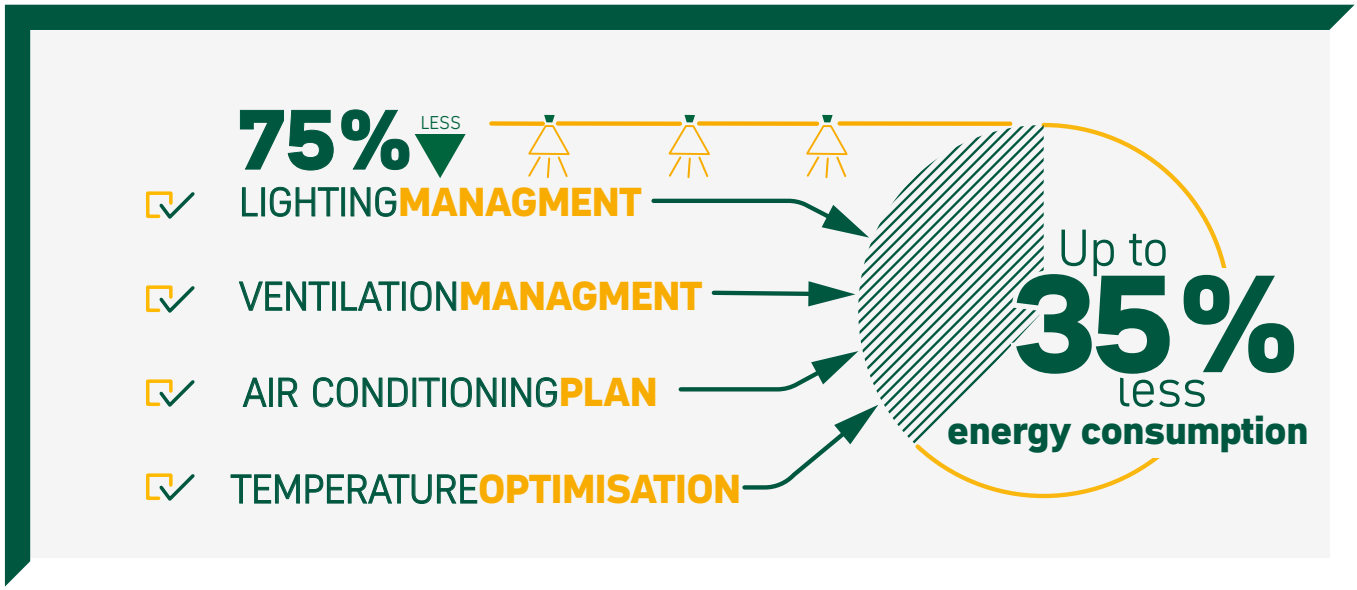
3.1 OPTIMISED USE OF AREA AND SPACE

In addition to the construction method, automated warehouse technology plays a central role when it comes to space optimisation. System components such as stacker cranes, shuttle systems or compact container storage systems allow for optimal utilisation of the available space. **Compact container storage systems such as the Jungheinrich PowerCube are particularly impressive, with a storage density four times higher than a warehouse with shelving units** – this is because no cross beams are necessary; the loading devices are stacked directly on top of one another and the air gaps are minimised. In addition, neither excavation nor a conventional sprinkler system are necessary, which further reduces construction effort.

Moreover, the compact design and automation lead to additional energy savings potentials, for example in temperature regulation, ventilation, air conditioning and lighting. **This means that up to 75% fewer light fixtures are needed and up to 35% less energy is consumed overall[6].**

Particularly effective implementations of this principle are the deep-freeze warehouse, where the energy required to cool the more compact space can be minimised, and the dark warehouse, a fully automated storage area that requires no permanent lighting or continuous heating and ventilation. This design enables significant savings in energy and operating costs.

Overall, it is clear that those who opt for ASRS solutions in their warehouse planning not only reduce their ecological footprint but also benefit from lower construction costs, reduced space consumption and greater future viability. Sustainability begins with the structure of the warehouse but naturally continues in the daily operation of the automated warehouse system, where the right material handling solutions also meet high ecological standards.



6) 4flow study: Sustainable warehousing: Practical measures for emission and cost reduction. Tom Binsfeld, Jan-Niklas Grafe, Wendelin Gross, Iwan Nikitin, Jan Oppermann, p. 12.

#3 SUSTAINABILITY ASPECTS OF AUTOMATED WAREHOUSE SYSTEMS

3.2 REDUCED ENERGY CONSUMPTION AND LOWER EMISSIONS

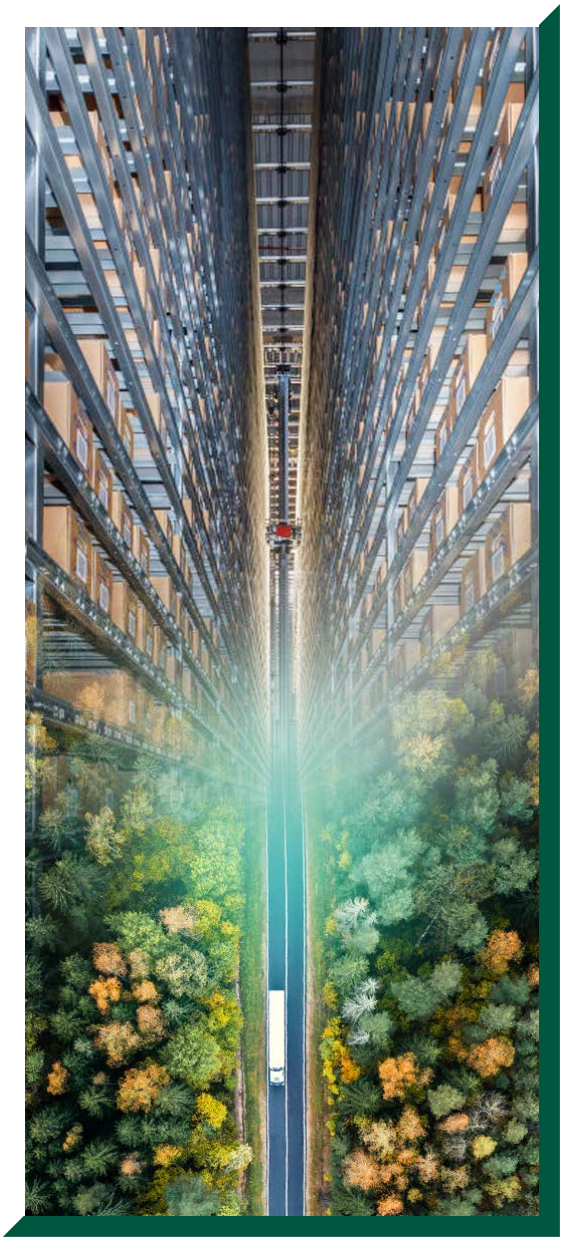
Automated warehouse systems demonstrate their full sustainability potential in everyday use. In addition to logistical advantages, they offer clear ecological benefits – particularly with regard to energy efficiency, resource conservation and low-emission processes.

An automated warehouse generally consumes less energy than a manual one and produces lower emissions[7]. According to a 4flow study, warehouse automation can lead to a reduction of up to 35% in CO_2e emissions[8,9]. Additionally, the switch to automation at the Norwegian furniture retailer Bohus, for example, has resulted in energy savings of 17%[10].

Part of the savings arise from the holistic optimisation of processes: the combination of digitalisation and automation is key in this case. **With intelligent warehouse management systems, routes are calculated and optimised**, unnecessary trips are avoided and material flows are controlled with the utmost precision. This minimises the amount of energy required per pick, while picking times are also reduced.

Artificial intelligence (AI) can further amplify this effect. It enables even more proactive control, exemplified by inventory forecasts or the early detection of disruptions in material flow. Additionally, digital warehouse management provides **maximum transparency** regarding goods movements and inventories. This helps to avoid surplus stock, which consumes unnecessary space and energy. Resources along the supply chain are thus conserved or used more efficiently.

Another advantage: **automated warehouse systems significantly reduce picking errors**. Every incorrect shipment not only causes dissatisfied customers and additional internal work, but often also results in a return. Fewer returns mean fewer CO_2e emissions across the entire supply chain – for example, due to fewer transport journeys.



7) This is corroborated by our calculations and customer projects, see chapters 4.1 and 4.2.
8) In addition to carbon dioxide, there are other climate-damaging greenhouse gases such as methane or nitrogen trifluoride. To make these comparable, they are indexed CO_2 equivalents. That is why we refer to CO2e emissions, where the "e" stands for "equivalents".
9) 4flow study: Sustainable warehousing: Practical measures for emission and cost reduction. Tom Binsfeld, Jan-Niklas Grafe, Wendelin Gross, Iwan Nikitin, Jan Oppermann, p. 12.
10) Bohus reduserte energiforbruket gjennom automatisering, https://kommunikasjon.ntb.no/pressemelding/18022479/bohus-reduserte-energiforbruket-gjennom-automatisering?publisherId=17848596&lang=no, as at 21/05/2025.

#3 SUSTAINABILITY ASPECTS OF AUTOMATED WAREHOUSE SYSTEMS

3.2 REDUCED ENERGY CONSUMPTION AND LOWER EMISSIONS

Since 48% of the energy consumption in warehouse operations is attributable to the warehouse technology employed, ASRS solutions provide concrete levers for further energy savings.

Three technical principles of stacker cranes contribute significantly to this:

1. INTELLIGENT TRAVEL CONTROL

Coordinated movement sequences, such as the simultaneous arrival of both axes, the lifting mechanism and the chassis, at the compartment can significantly reduce energy consumption.

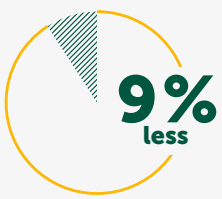
2. REDUCTION OF POWER PEAKS

Short-term power peaks can be prevented by using cross-aisle start-up control or asynchronous starting. This not only reduces energy consumption and operating costs but also allows for more efficient dimensioning of the infrastructure, such as transformers or cable cross-sections.

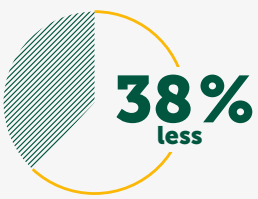
3. ENERGY RECOVERY AND USE OF SUPERCAPS

Modern ASRS solutions utilise regenerative technologies: energy released, for example during braking, is fed back into the system or stored. Supercapacitors (SuperCaps) are used for local intermediate storage, enabling later reuse of the energy.

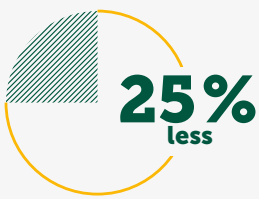
Only the effective interplay of efficient technology and intelligent process control makes automated warehouse systems a key component for resource conservation and CO_2e reduction – from the system's power consumption to the balance of the entire supply chain.



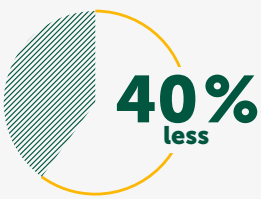
less energy consumption through asynchronous start of the axes



lower energy costs through axis connection and energy recovery



lower energy costs with SuperCaps



fewer peaks in energy consumption

11) Grünbuch der nachhaltigen Logistik. Gerald Gregori, Thomas Wimmer, p. 58.

#3 SUSTAINABILITY ASPECTS OF AUTOMATED WAREHOUSE SYSTEMS

3.3 ENHANCED HEALTH AND SAFETY

Automated warehouse systems not only improve efficiency and energy balance but also make a significant contribution to promoting the health, satisfaction and safety of employees – a key dimension of corporate sustainability.

By eliminating heavy manual tasks such as lifting, bending and carrying, the physical strain on employees is significantly reduced. Ergonomics in the workplace are noticeably improved. A comprehensive analysis of 250 case studies by the Fraunhofer Institute for Manufacturing Engineering and Automation shows that even simple ergonomic measures have a major impact:

- 65% reduction in musculoskeletal disorders.
- 57–73% reduction in days of incapacity for work on average.
- And, at the same time, a 25% increase in productivity on average[12].

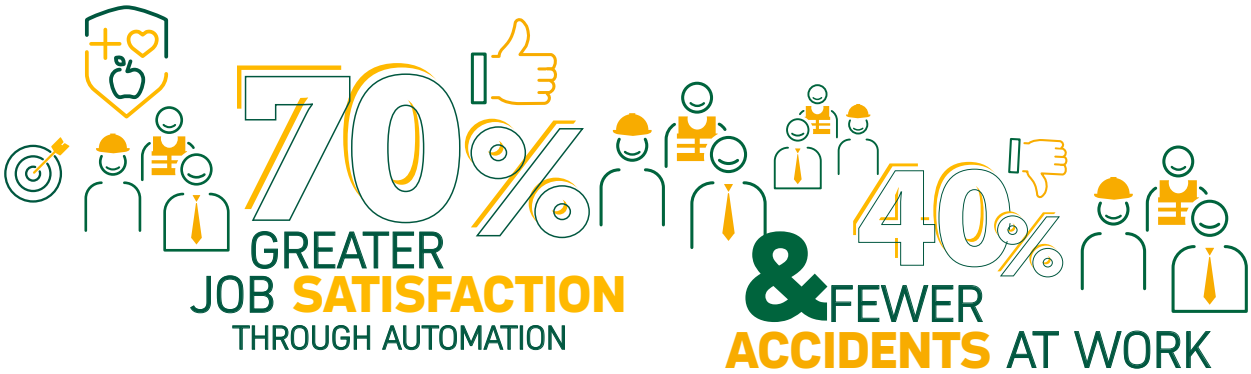
Especially in demanding environments, such as deep-freeze warehouses, transitioning to ASRS solutions can provide significant relief. On the one hand, these jobs are becoming increasingly difficult to fill, particularly due to the skills shortage. On the other hand, automation enables a reduction in tasks performed under extreme conditions or in shift work. This alleviates the physical and mental burden on employees, thus making a significant contribution to their long-term employability.

Improved working conditions have been shown to significantly enhance employee satisfaction. A cross-industry McKinsey study, which also includes employees in logistics and production, concludes that automation increases **job satisfaction by up to 70%**[13]. In times of skills shortages, this is a crucial factor for attracting new employees and retaining existing staff in the long term.

The international study "Automation from the Worker's Perspective" by MIT also confirms this trend. 44.9%[14] of surveyed employees report positive effects of automated technologies on comfort and safety in the workplace.

Safety is a key advantage of automated systems. They help to prevent accidents that previously often resulted in significant property damage and personal injury. This is achieved, among other things, by reducing manual interventions and also human errors. ASRS solutions, for example, take over repetitive tasks, protecting employees from accidents due to incorrect operation, overload or fatigue. Industry-standard figures often show **40% fewer workplace accidents** due to automation, while studies indicate at least **16% fewer serious accidents**[15], although these usually focus on only one aspect of automation.

Automated warehouse systems thus not only contribute to ecological and economic sustainability, but they also strengthen the social dimension: healthier and happier employees also mean a more sustainable company.



12) Cf. Ergonomie-Benefits - Kriterien zur Bewertung ergonomischer Maßnahmen in der Kosten-Nutzen-Analyse. Fraunhofer Institute for Manufacturing Engineering and Automation Daub, U., Ackermann, A., & Kopp, V. IPA – Stuttgart 2019.
13) Cf. A Future That Works: Automation, Employment, and Productivity. Jacques Bughin, Michael Chui, Martin Dewhurst, Katy George, James Manyika, Mehdi Miremadi, Paul Wilmott. McKinsey Global Institute 2017.
14) Cf. Automation from the Worker's Perspective. Ben Armstrong, Valerie K. Chen, Alex Cullar, Alexandra Forsey-Smerek, Julie Shah. MIT 2024.
15) Giuntella, O., Gihleb, R., & Stella, L. Industrial Robots, Workers' Safety, and Health. CESifo Working Paper No. 9809. Munich 2022, p. 33.

#4 USE CASES: ASRS AND SUSTAINABILITY

4.1 COMPARISON OF AUTOMATED AND MANUAL WAREHOUSES

Up to 18% lower CO2e emissions per year – this is the potential difference between an automated warehouse system and a manual narrow-aisle warehouse. This result is based on measurements conducted by our experts during a customer project. For this purpose, we have accurately recorded and balanced the emissions across the entire life cycle.

OUR APPROACH

We calculated the CO_2e emissions for a warehouse with production connection on an annual basis and for the entire life cycle – from raw materials through production and transport to use and end of life. Customer-specific values (e.g. specific CO_2e figures from the steel supplier) and typical average figures (e.g. German electricity mix) were utilised.

THE AUTOMATED WAREHOUSE AND THE MANUAL NARROW-AISLE WAREHOUSE IN DETAIL:

ASRS

Bearing dimension	[103x40x42]m
Pallet spaces	33,360 (geringerer Füllgrad)
Number AS/RS	5
Pallets	[1,300x900]mm
Pallet weight	Max. 750kg, Ø120kg

VNA

Bearing dimension	[110x77x17]m
Pallet spaces	31,000
Number EKX/ETV	7/10
Pallets	[1,300x900]mm
Pallet weight	Max. 750kg, Ø120kg

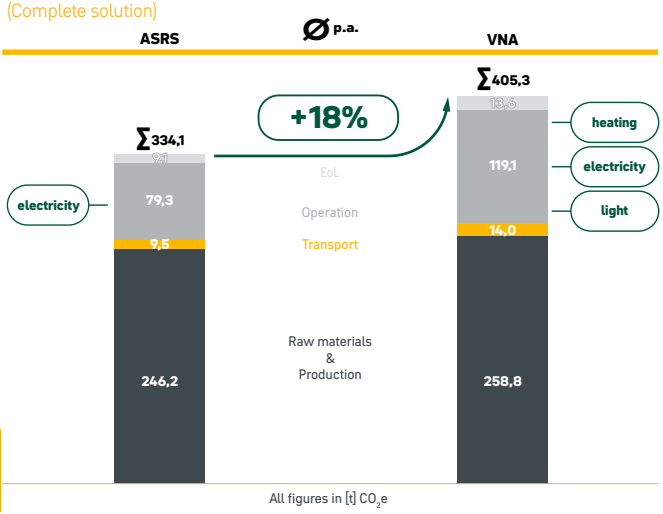
Throughput requirements	Value
Operating model	2 shifts → 16 operating hours per day
Peak factor	1,3 → 12 effective operating hours per day
Maximum system performance	120 pallet storage and retrieval
Average system performance	90 pallets (70-100 pallets / h for conveyor technology)
Operating days per year	250

RESULTS OF THE COMPARISON IN DETAIL

The analysis shows that the ASRS solution significantly reduces energy consumption and the CO_2e footprint – by up to 18% per year. Customers who opt for an automated warehouse system thus benefit greatly from this decision.

RESULTS OVERVIEW WITH PRODUCTION CONNECTION

(Complete solution)



All figures in [t] CO_2e

CONCLUSION

Increasing the level of automation helps to improve the Co2e2 footprint – during operation and over the entire life cycle.

Three main conclusions can be drawn from the results:

- **Long-term benefit:** the longer an automated warehouse system is in operation and the more efficient it needs to be, the better it performs compared to a manual warehouse.
- **Savings potential during use:** reduced lighting and heating significantly contribute to savings during the operational phase.
- **Additional leverage effects:** the use of green electricity and green steel greatly increases the sustainability impact.

#4 USE CASES: ASRS AND SUSTAINABILITY

4.2 GF AUTOMATES WITH JUNGHEINRICH

GF, a global manufacturer of flow solutions, commissioned Jungheinrich to transform its manual warehouse at the Seewis plant into a modern, highly automated warehouse. Today, the company benefits from greater energy efficiency – 31.6% energy savings per pick – and improved safety, along with increased material turnover and a reduced warehouse footprint.

GF chooses Jungheinrich

With around 200 employees, the company's plant in Seewis, Switzerland, produces approx-imately 1.3 million plastic valves and 2 million plug-in fittings annually at its Seewis location in Switzerland. The product range includes more than 17,000 different items. The aim of the project with Jungheinrich was the complete transformation of the outdated manual warehouse into an automated warehouse system, including both the systems (high-bay warehouse, automated small parts warehouse, WMS) and the processes (new workflows, WMS interface, SAP). The entire planning, implementation and commissioning had to occur without disrupting production and delivery capabilities.

The results – with a focus on sustainability

Nico Bleisch, Operational Excellence Manager at GF, sums up the major progress from a manual to an automated warehouse: "Today, we work much more efficiently and with greater process reliability. Pre-picking enables a reliable just-in-time supply, thus strengthening the stability of our production processes and our delivery capability. Clear, system-managed processes without interruptions increase accuracy, create transparency and facilitate the early identification of bottlenecks. This allows us to utilise existing resources in a more targeted manner and with much greater efficiency."

The positive sustainability effects resulting from the automation in GF's new warehouse are particularly pleasing. They underscore the advantages outlined in chapter 3.

Space requirements

Thanks to a taller design (19.4 metres instead of 17.6 metres), the required floor space was reduced to 1,240 m2 (instead of 1,472 m2). Automated warehouse systems, as described in chapter 3.1, can help to reduce soil surface sealing.

Energy efficiency

The best way to compare energy efficiency is to look at the energy consumption per pick. This was 7.043 kWh in the manual warehouse and only 4.823 kWh in the automated warehouse system – alongside an overall increase in material turnover. The savings per pick thus amount to 31.6% – a marked improvement in energy efficiency! Considering productivity in relation to energy usage results in an increase of 45.8% output per unit of energy.

Safety

The new automated warehouse system has significantly reduced the risk of accidents.

Employee satisfactionand ergonomics

Materials are automatically delivered to ergonomically designed workstations, thereby eliminating unnecessary walking and heavy lifting. Height-adjustable workstations, ball bearing tables and pick- and put-to-light systems make work easier. System-guided processes reduce stress, create transparency and enable clearly defined tasks and responsibilities, all of which has, according to GF, had a positive impact on employee satisfaction.

#5 THREE STEPS TO AN AUTOMATED WAREHOUSE SYSTEM

Be it stacker cranes, shuttle systems or compact container storage systems like the Jungheinrich PowerCube, Jungheinrich's experts plan and implement the exact automated warehouse system that meets your specific requirements. At the same time, we also consider efficiency and sustainability: compact design, energy-efficient solutions and resource-conserving processes form part of our planning from the very outset. In three coordinated steps, we support you until the successful commissioning of your system – and beyond.

1. PLANNING & PROJECT MANAGEMENT

The process begins with a thorough analysis of your needs. With our material flow consulting, as well as rough and detailed planning, we identify the right level of automation and the optimum system architecture. We place particular emphasis on sustainability and future viability: our solutions are expandable and adaptable, allowing you to remain flexible as volumes grow or processes change.

2. IMPLEMENTATION & SYSTEM INTEGRATION

Only a partner who excels in all trades can ensure that all systems work together perfectly: as a general contractor with decades of experience, we offer all solutions for your automated warehouse system from a single source. We provide turnkey solutions, including ASRS, materials handling equipment and integration with existing systems. We always ensure that all new components integrate seamlessly and all processes run smoothly.

3. SERVICE, SUPPORT & MODERNISATION

Even after commissioning, we are always there for you: with over 6,200 customer service engineers worldwide and 24/7 support. To ensure optimal operation of your system, we support you with maintenance, safety checks, repairs and inspections. Spare parts are always on-site to minimise downtimes. You also have full cost control, thanks to a range of service packages.

An essential part of our sustainability strategy, as with the reconditioning of our industrial trucks, is the adaptation and modernisation of logistics systems that have been in use for many years. This allows us to significantly extend the service life of the systems, as it is usually sufficient to modernise the electronics and control systems.

#6 6. CONCLUSION: GREATER SUSTAINABILITY THROUGH AUTOMATION

Automated warehouse systems based on ASRS solutions demonstrably increase the sustainability of a warehouse. At the same time, they also ensure greater transparency and flexibility.

The sustainability potential presented in chapter 3 – from higher energy efficiency and reduced space requirements to increased safety and employee satisfaction – is not a theoretical promise but is, in fact, measurable in practice. The projects presented in chapter 4 serve as impressive evidence of this.

Jungheinrich has demonstrated that it is the ideal partner for sustainably transforming warehouses and making them future-proof. After all, those who entrust us with their automation lay the foundation for greater efficiency and sustainable material handling.

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ISO 9001
ISO 14001

The German production facilities in Norderstedt, Moosburg, Landsberg and Kaltenkirchen are certified.

CE

Jungheinrich trucks conform to the European Safety Requirements.

Jungheinrich Aktiengesellschaft

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